New Cordierite Diesel Particulate Filters for Catalyzed and Non-Catalyzed Applications

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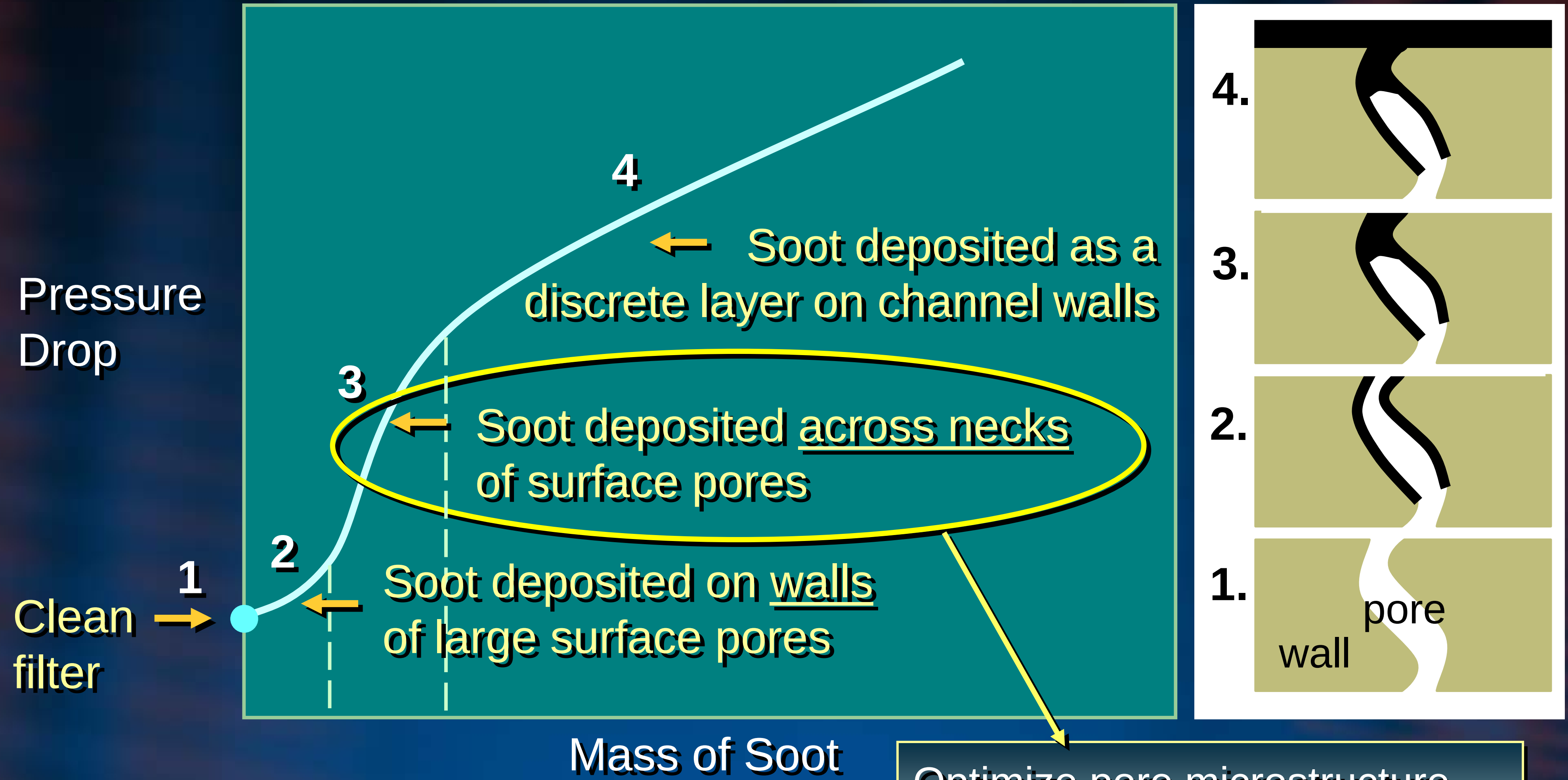
Outline

- General overview of pressure drop behavior
- Relationship of pressure drop to pore microstructure for bare cordierite filters
- Effects of catalyst on pressure drop
- Optimization of pore microstructure for pressure drop, filtration efficiency, strength, and thermal mass

Pressure Drop versus Soot Loading



Optimize pore microstructure to minimize effect of soot in wall

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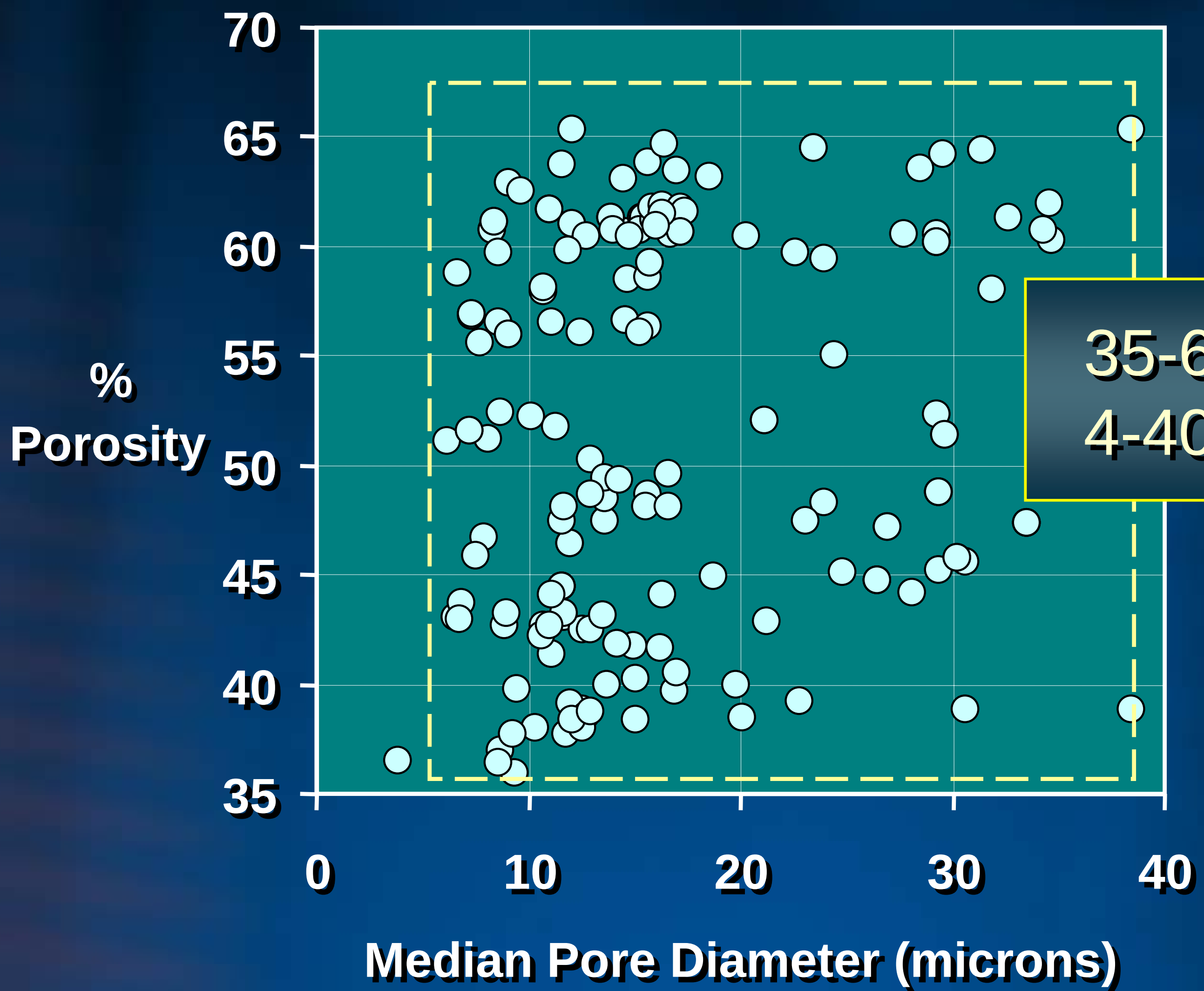
Experimental Study

- Objective: Quantify relationship between pressure drop and pore microstructure and utilize to design optimized filter
  - Fabricated 2” x 6” cordierite filters (200 cpsi) with over 100 different pore microstructures
  - Characterized %porosity, median pore size, and width of pore size distribution by mercury porosimetry
  - Measured clean and artificial soot-loaded pressure drop vs flow rate at room temperature
  - Derived a model for pressure drop in terms of pore parameters
  - Catalyzed selected candidates to determine optimum pore microstructure for catalyzed filter

Porosity and Median Pore Size



35-65% porosity
4-40 μm pore size

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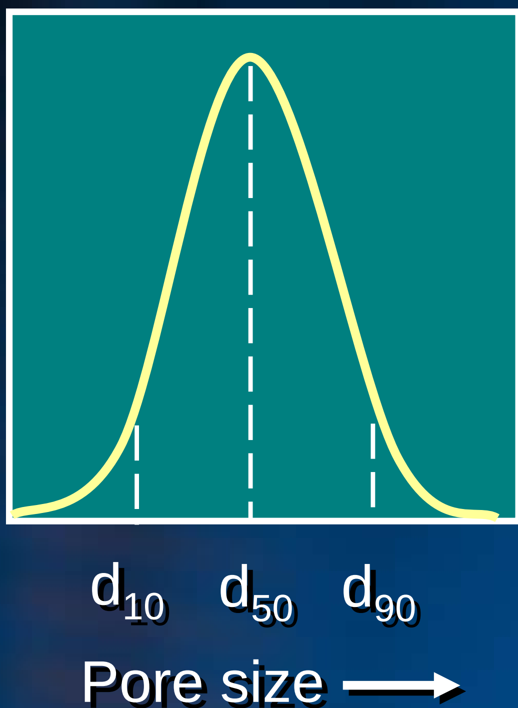
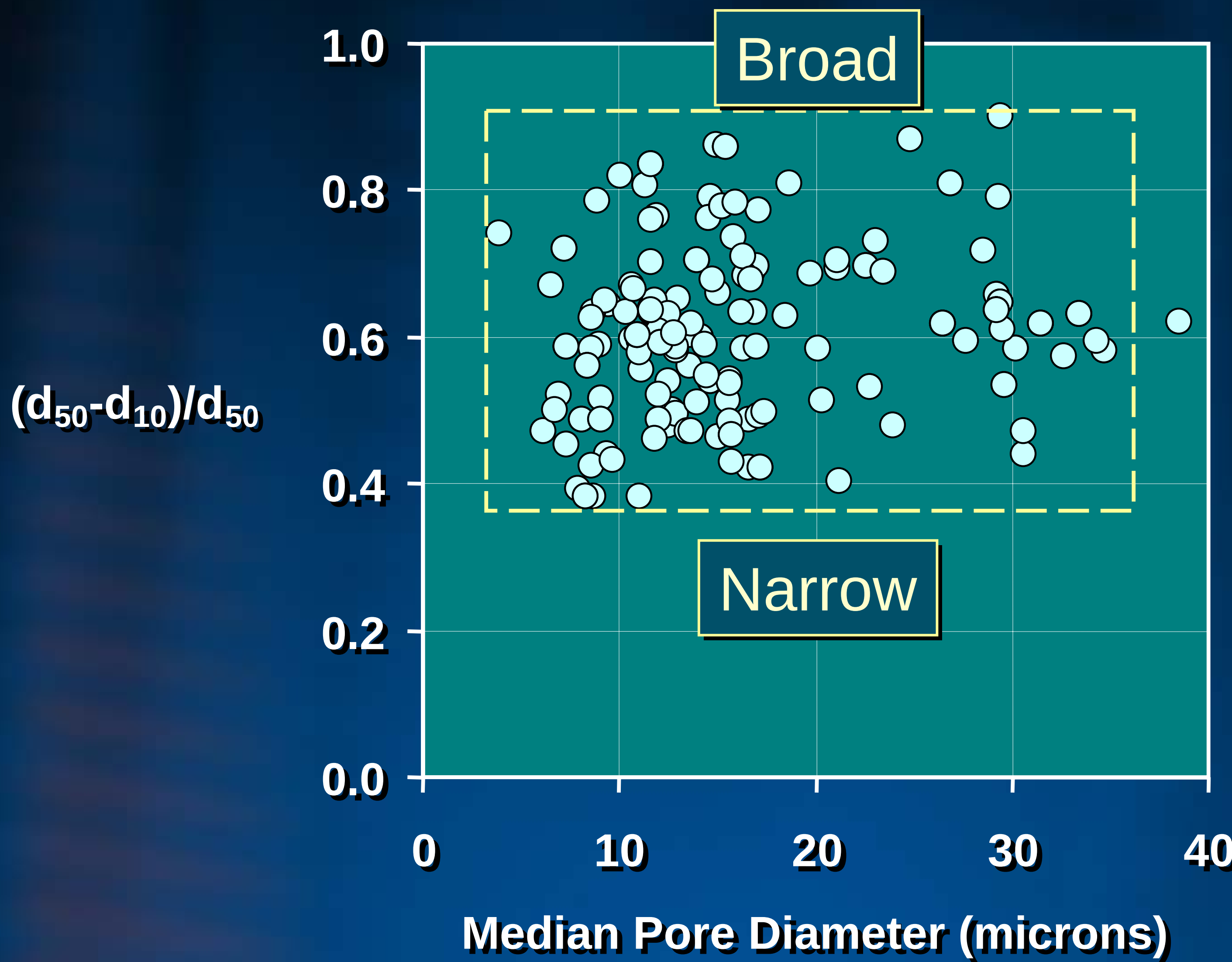
Pore Size Distribution



Measures of the width of the pore size distribution curve:

Full width:	$(d_{90}-d_{10})/d_{50}$
Coarse fraction:	$(d_{90}-d_{50})/d_{50}$
Fine fraction:	$(d_{50}-d_{10})/d_{50}$

Pore Size Distribution



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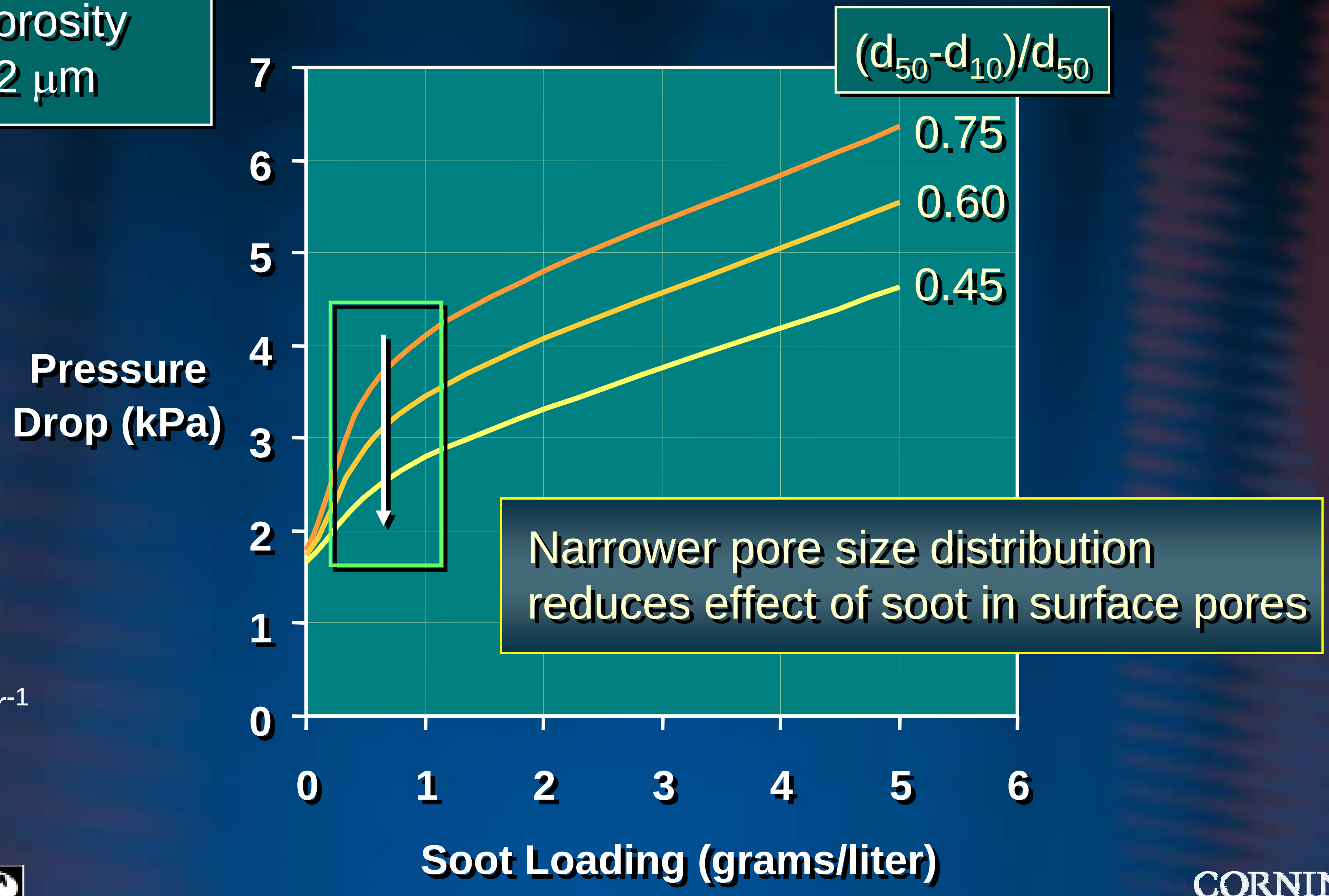
Key Learnings from Data Analysis

- Clean pressure drop decreases for larger values of (%porosity)(median pore size)^2
  - Consistent with models of flow through cylindrical capillary pores
  - Median pore size is dominant
- Soot-loaded pressure drop decreases for larger values of %porosity and smaller values of $(d_{50}-d_{10})/d_{50}$, narrower pore size distribution
  - Better pore connectivity
  - Lower gas velocity through pore necks
  - Less dense packing of soot in near-surface pores

Curves Computed from Regression Equations: Effect of Pore Size Distribution

50% Porosity
d_{50} = 12 μm



2” x 6”
200/12
144,000 hr^{-1}

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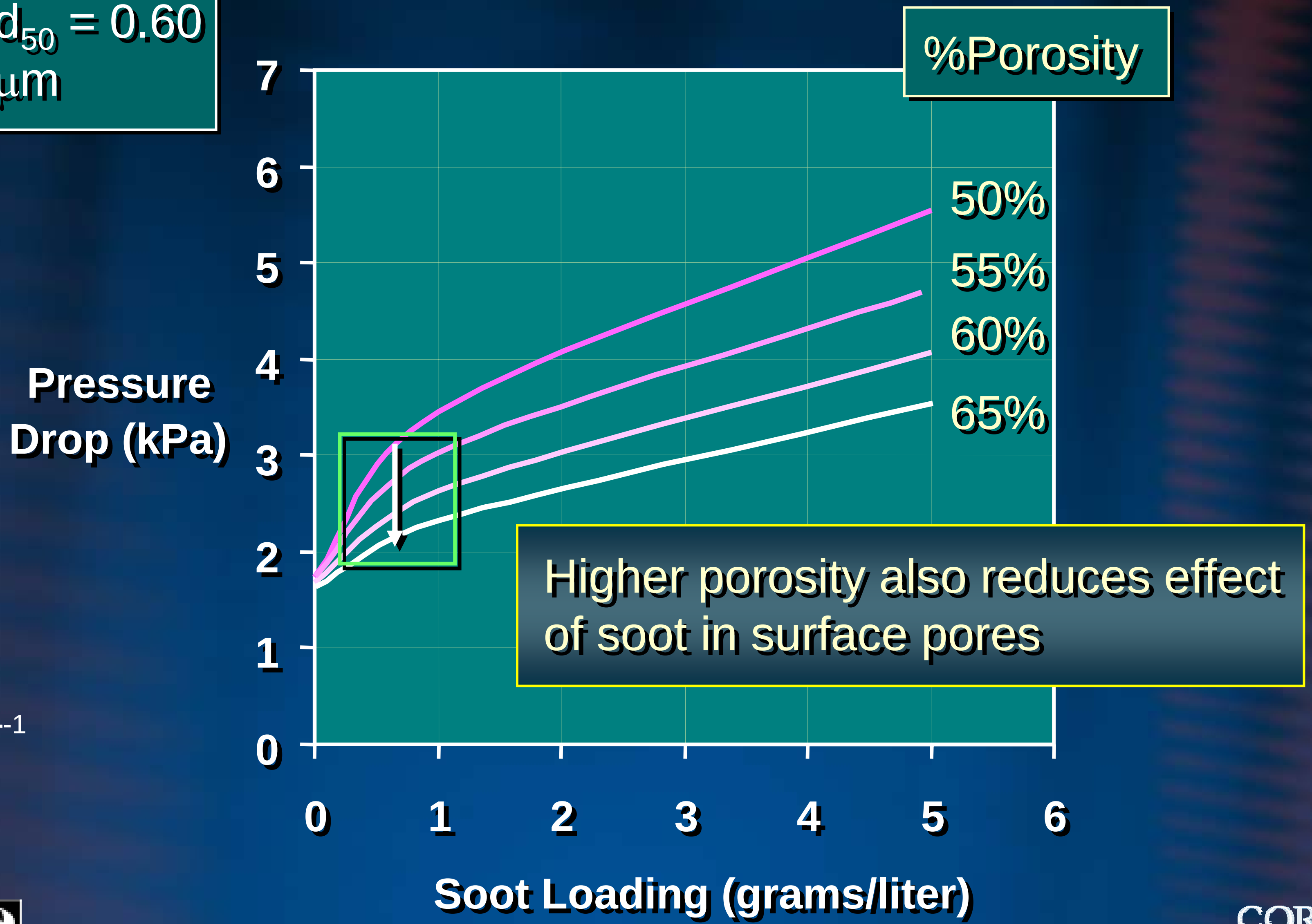
Curves Computed from Regression Equations: Effect of Porosity

$(d_{50}-d_{10})/d_{50} = 0.60$
$d_{50} = 12\ \mu m$

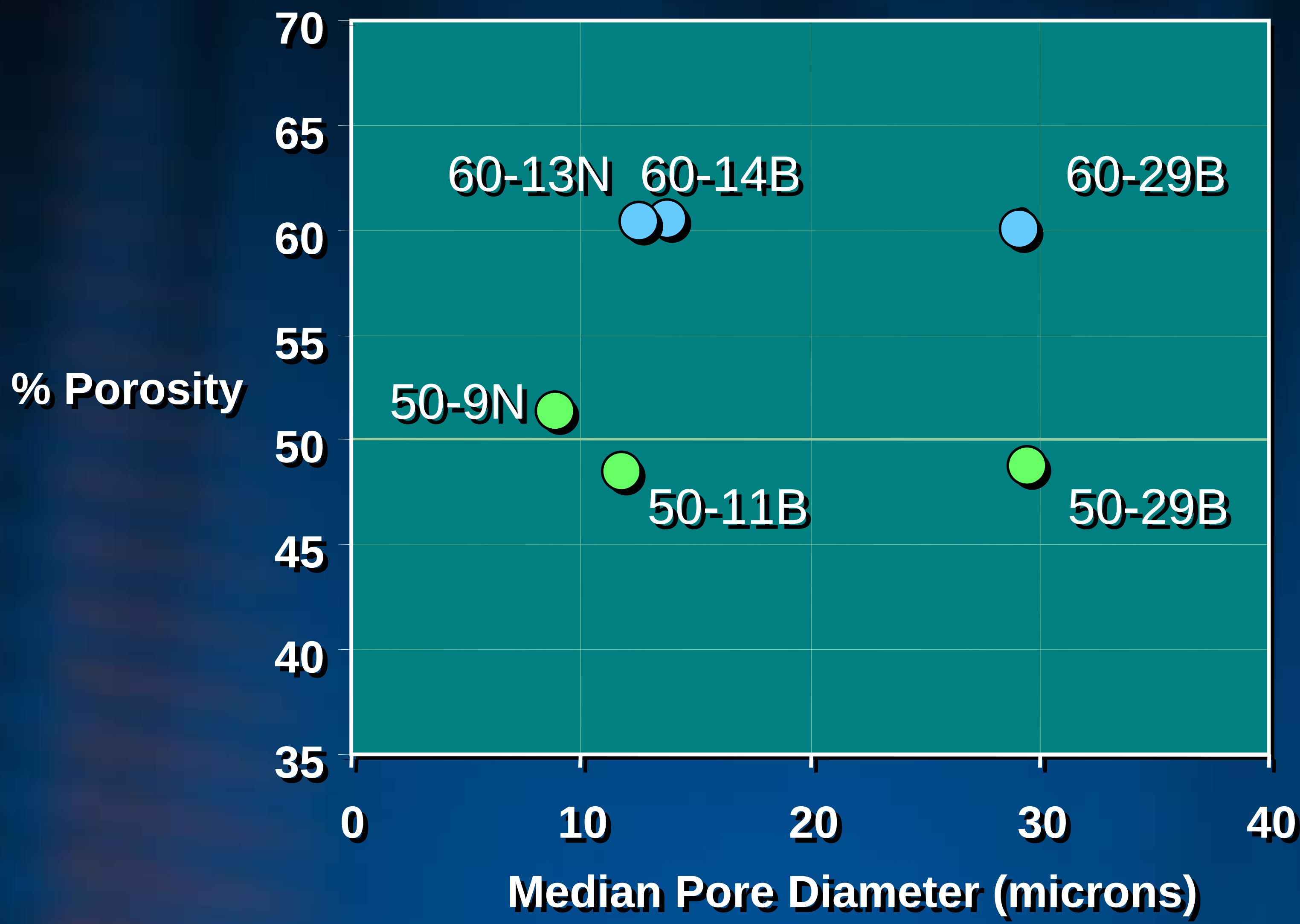


2” x 6”
200/12
144,000 hr^{-1}

Catalysis Coating Study

- Six cordierite materials with range in pore microstructures
- 2” x 6” filters, 200 cpsi, 12 mil walls
- Artificial soot loaded and pressure drop tested
- Soot burned out at 650^{o}C
- Catalyzed and soot-loaded pressure drop re-measured
- Two catalyst systems examined
  - Detailed results for System “A”
  - Summary of System “B” versus “A”

Porosity and Median Pore Size



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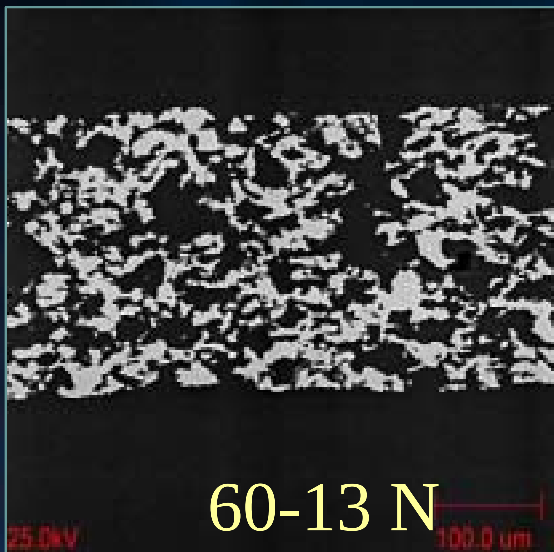
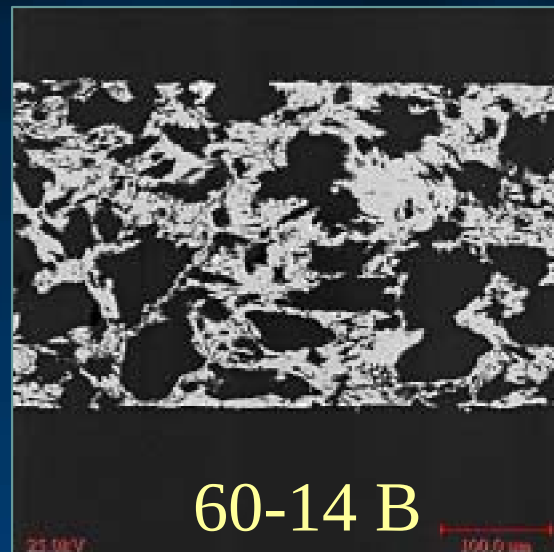
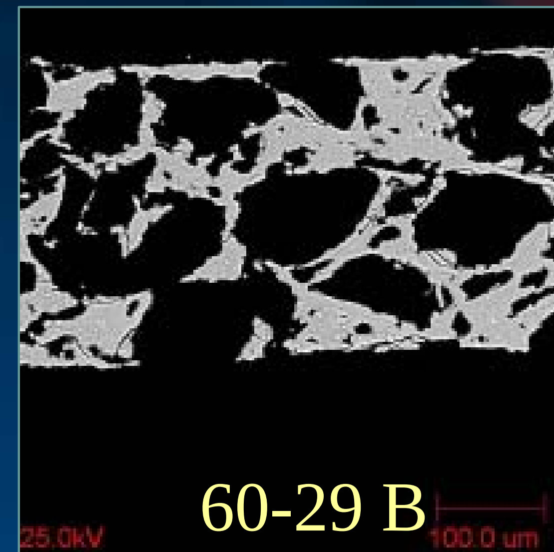
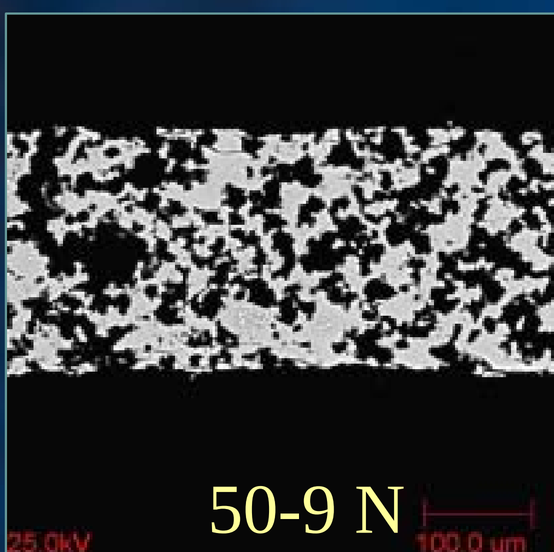
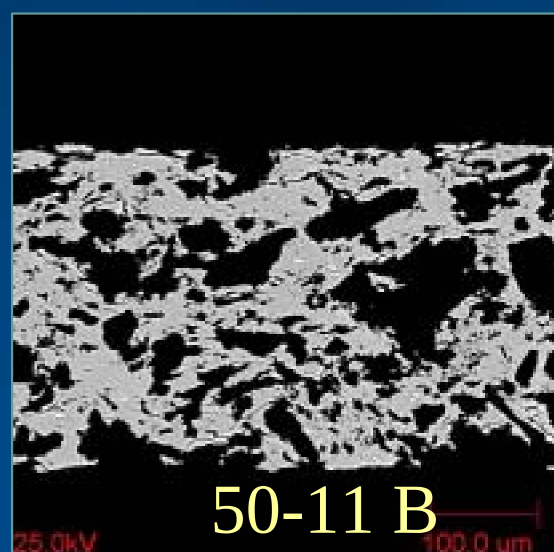
Examples of Pore Microstructures

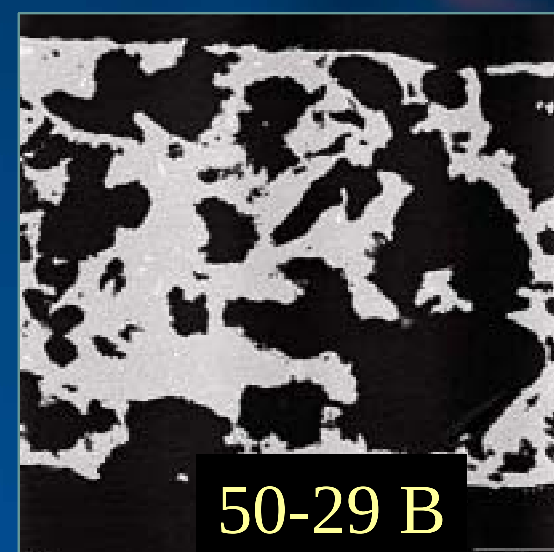












100 μm

Soot-Loaded Pressure Drop of Catalyzed Filters

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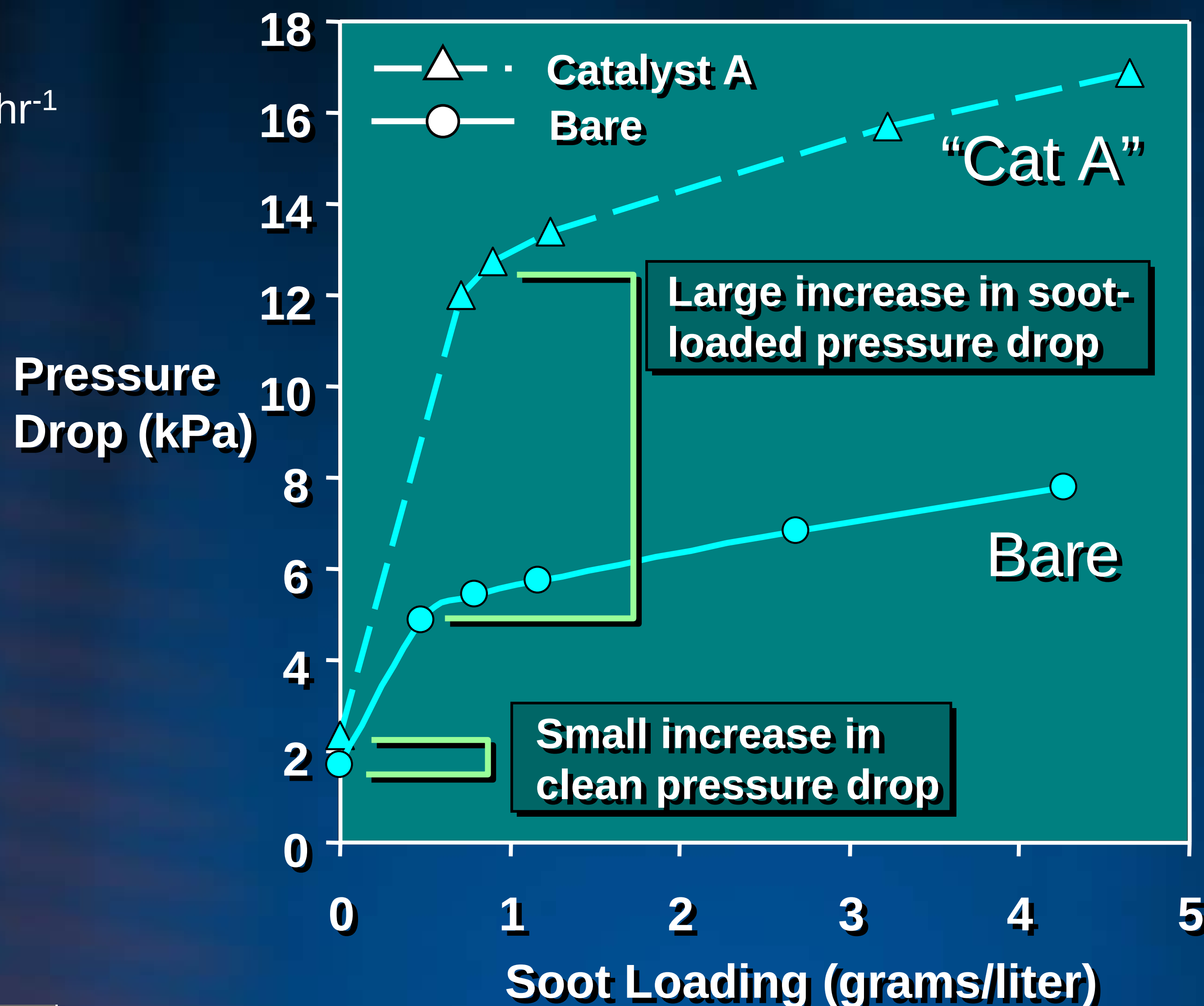
Bare & Catalyzed Pressure Drop: 50% Porosity

2” x 6”
200/12
144,000 hr^{-1}



50-11B

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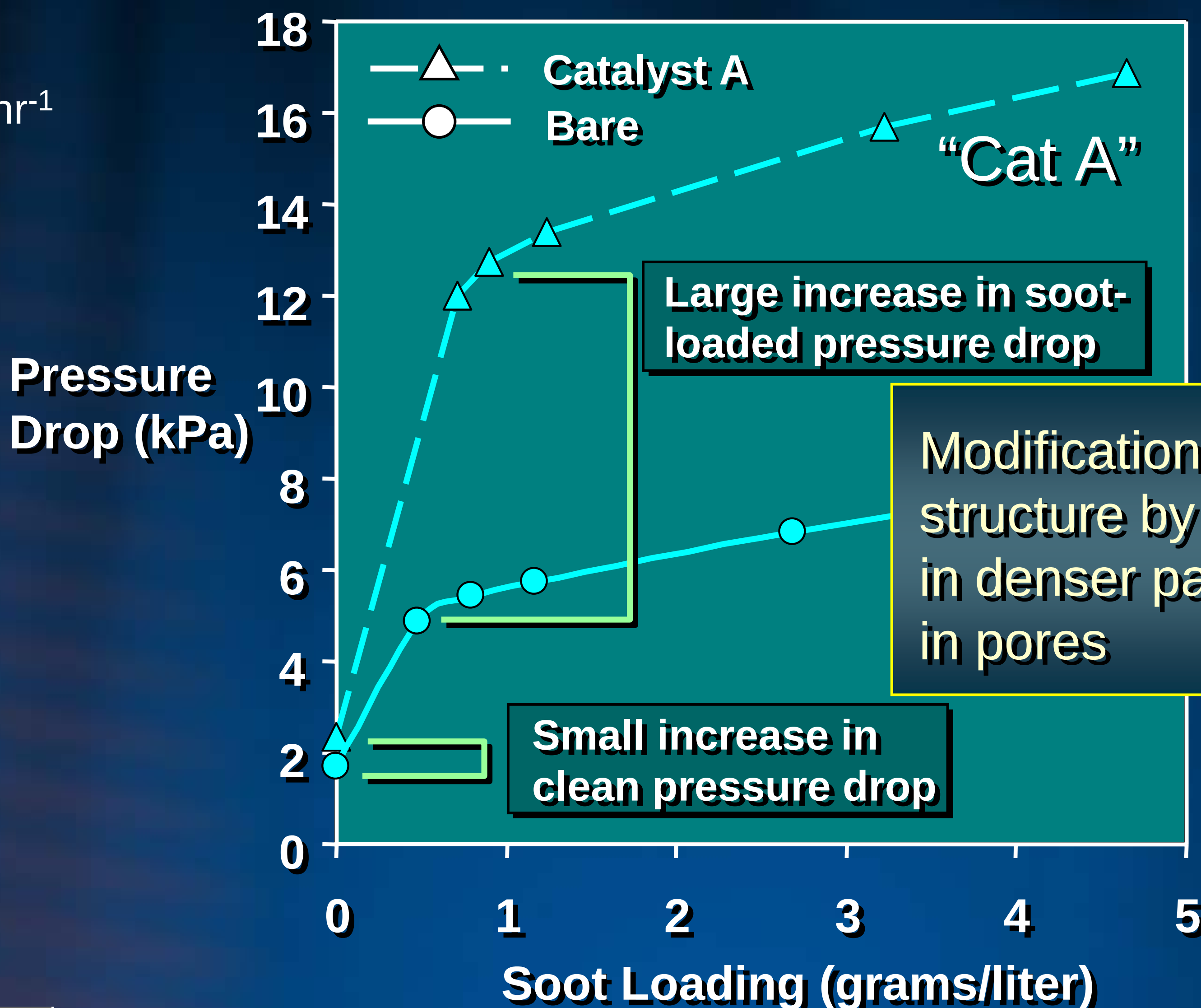
Bare & Catalyzed Pressure Drop: 50% Porosity

2" x 6"
200/12
144,000 hr^{-1}



50-11B

Modification of pore micro-structure by catalyst results in denser packing of soot in pores

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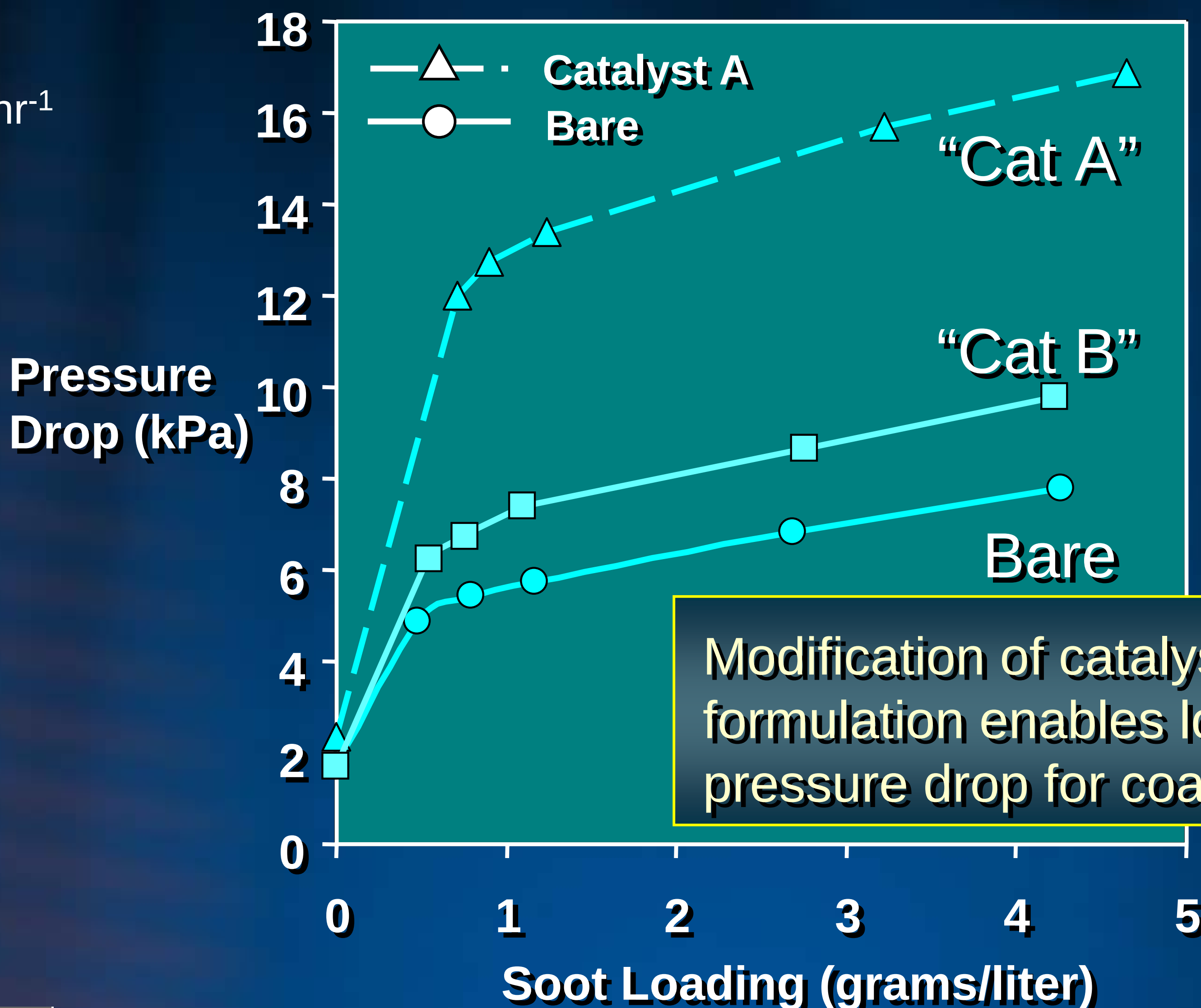
Bare & Catalyzed Pressure Drop: 50% Porosity

2” x 6”
200/12
144,000 hr^{-1}



50-11B

Modification of catalyst formulation enables low pressure drop for coated 50-11B

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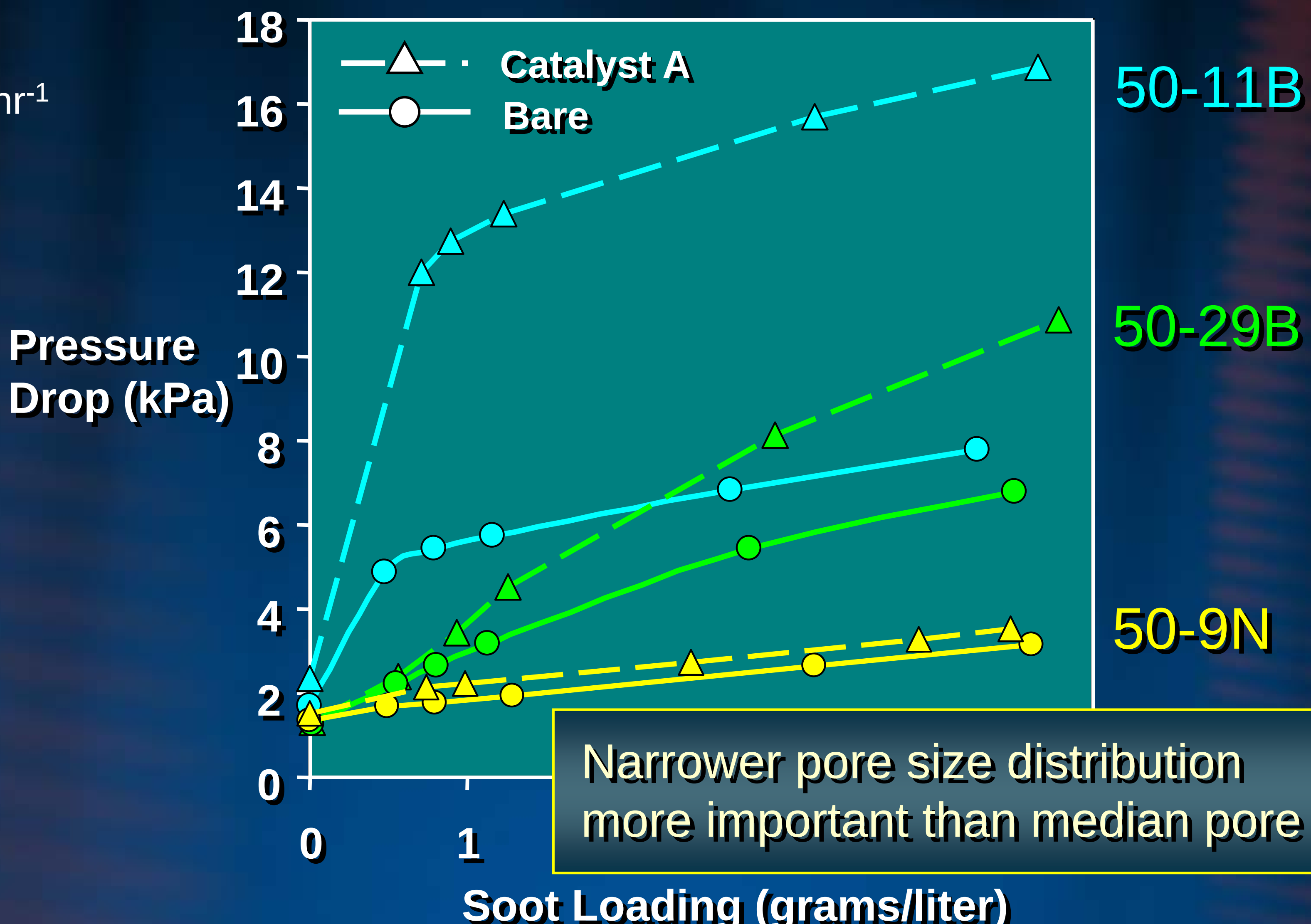
Bare & Catalyzed Pressure Drop: 50% Porosity

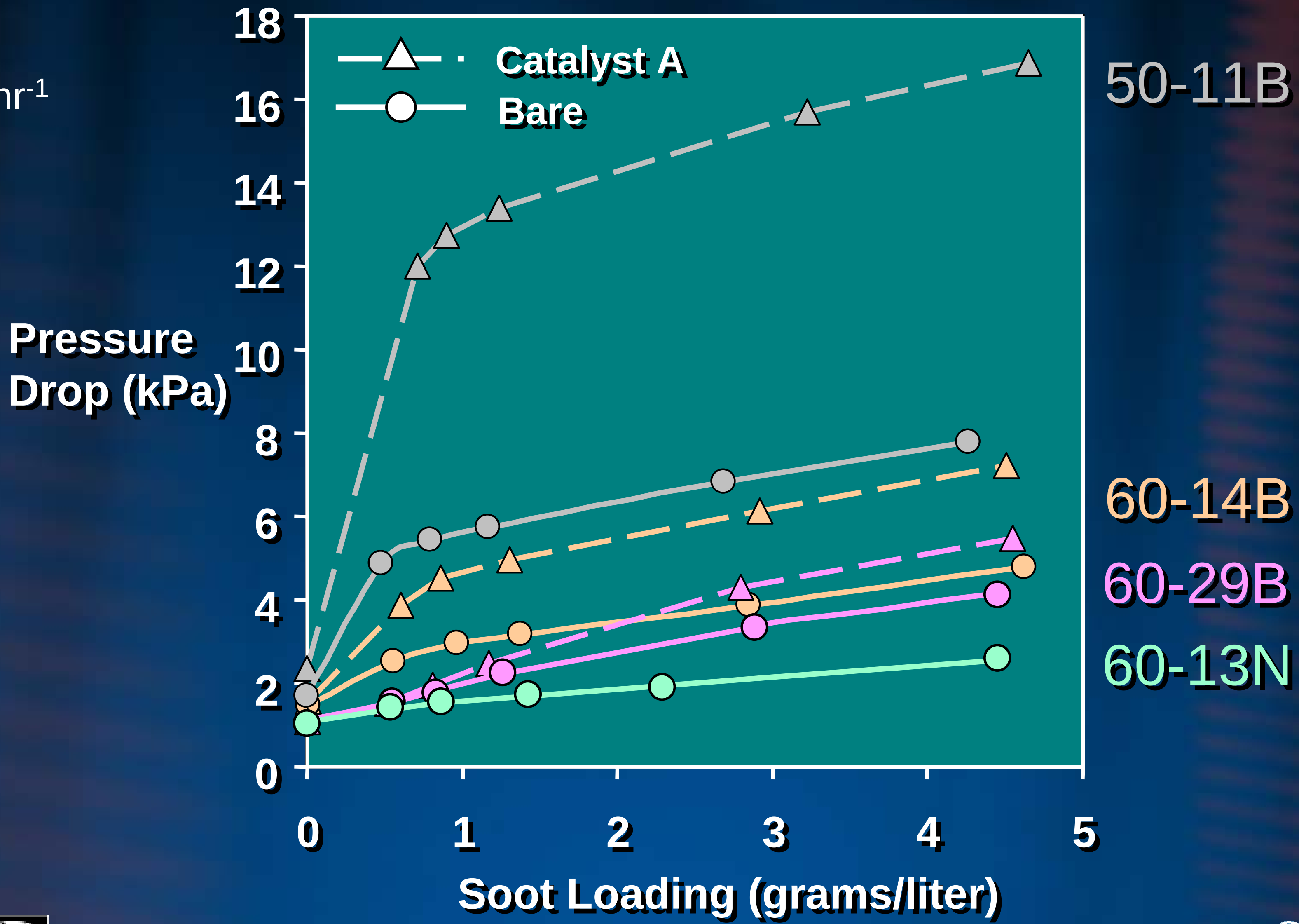
2" x 6"
200/12
144,000 hr^{-1}



Narrower pore size distribution more important than median pore size

Bare & Catalyzed Pressure Drop: 60% Porosity

2" x 6"
200/12
144,000 hr^{-1}



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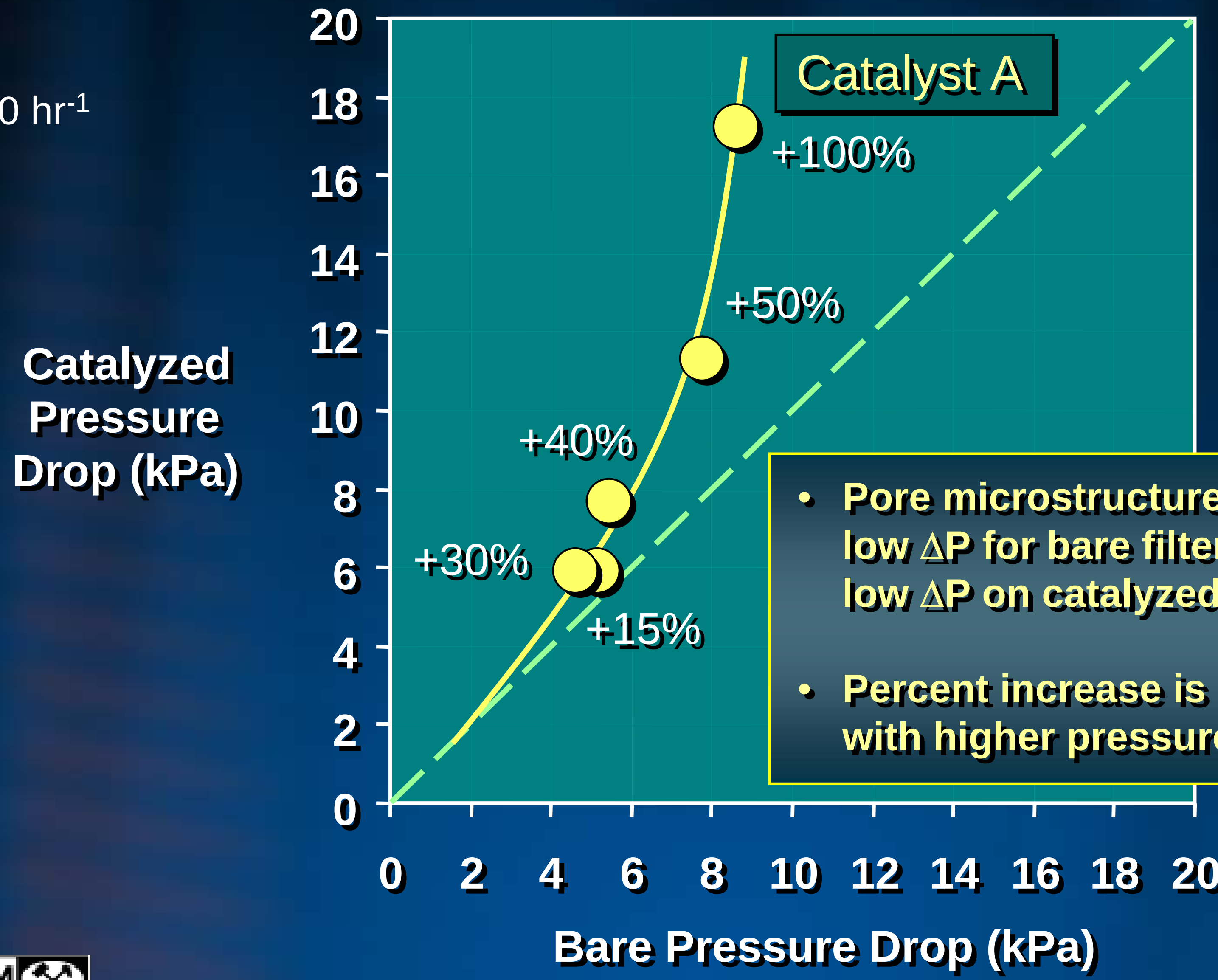
Pressure Drop Summary (5 grams/liter soot loading)

2” x 6”
200/12
144,000 hr^{-1}



- Pore microstructures that yield low ΔP for bare filters also provide low ΔP on catalyzed filters
- Percent increase is larger for filters with higher pressure drop

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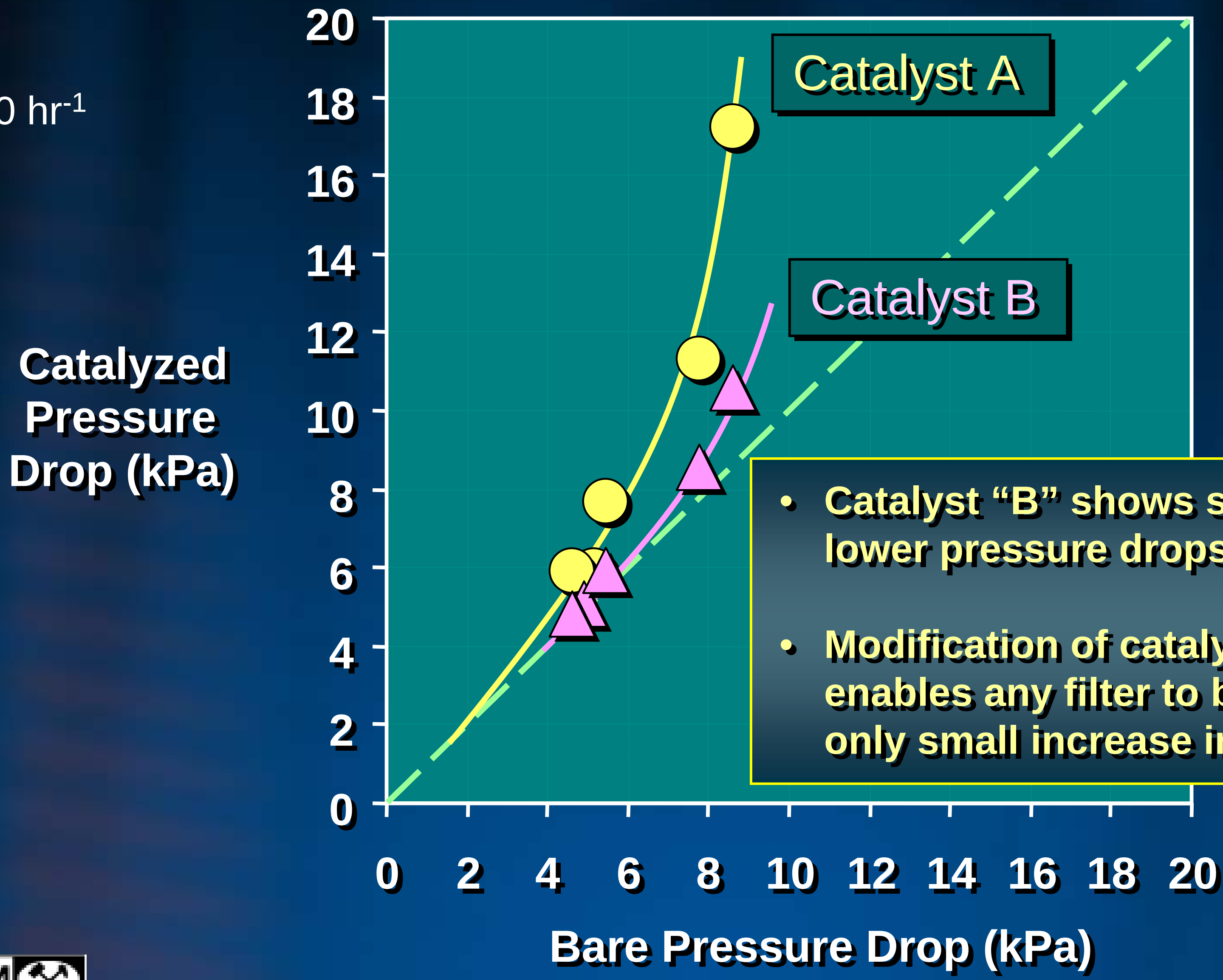
Pressure Drop Summary (5 grams/liter soot loading)

2” x 6”
200/12
144,000 hr^{-1}



- **Catalyst “B” shows similar trend, lower pressure drops**
- **Modification of catalyst formulation enables any filter to be catalyzed with only small increase in pressure drop**

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Thermal Durability during Regeneration

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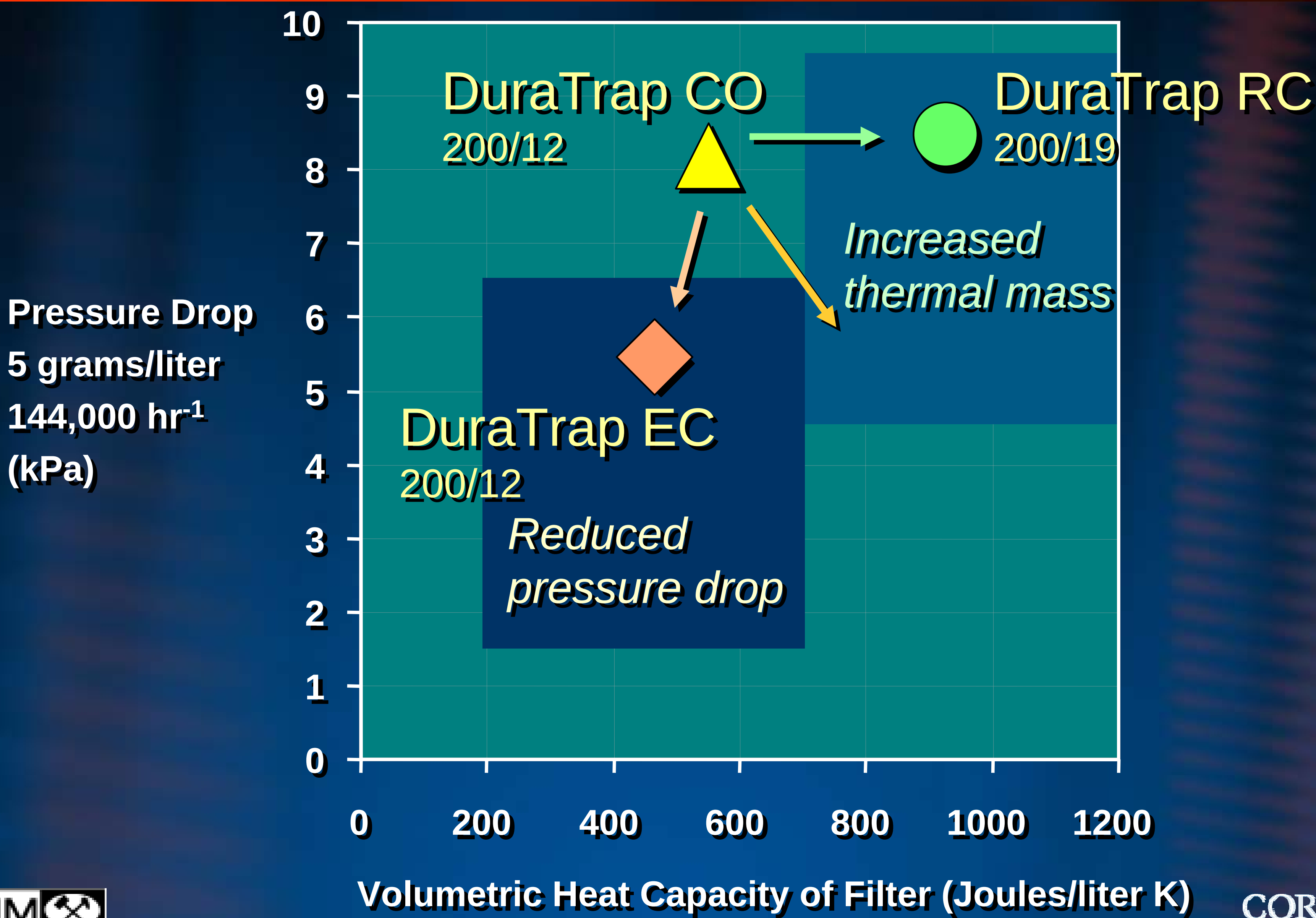
Regeneration and Volumetric Heat Capacity

- Temperatures reached during uncontrolled regenerations must be minimized for survivability of both filter and catalyst
- Peak temperature is reduced for filters with high “thermal mass” (heat capacity per unit volume)

Pressure Drop vs Volumetric Heat Capacity of Bare Filters



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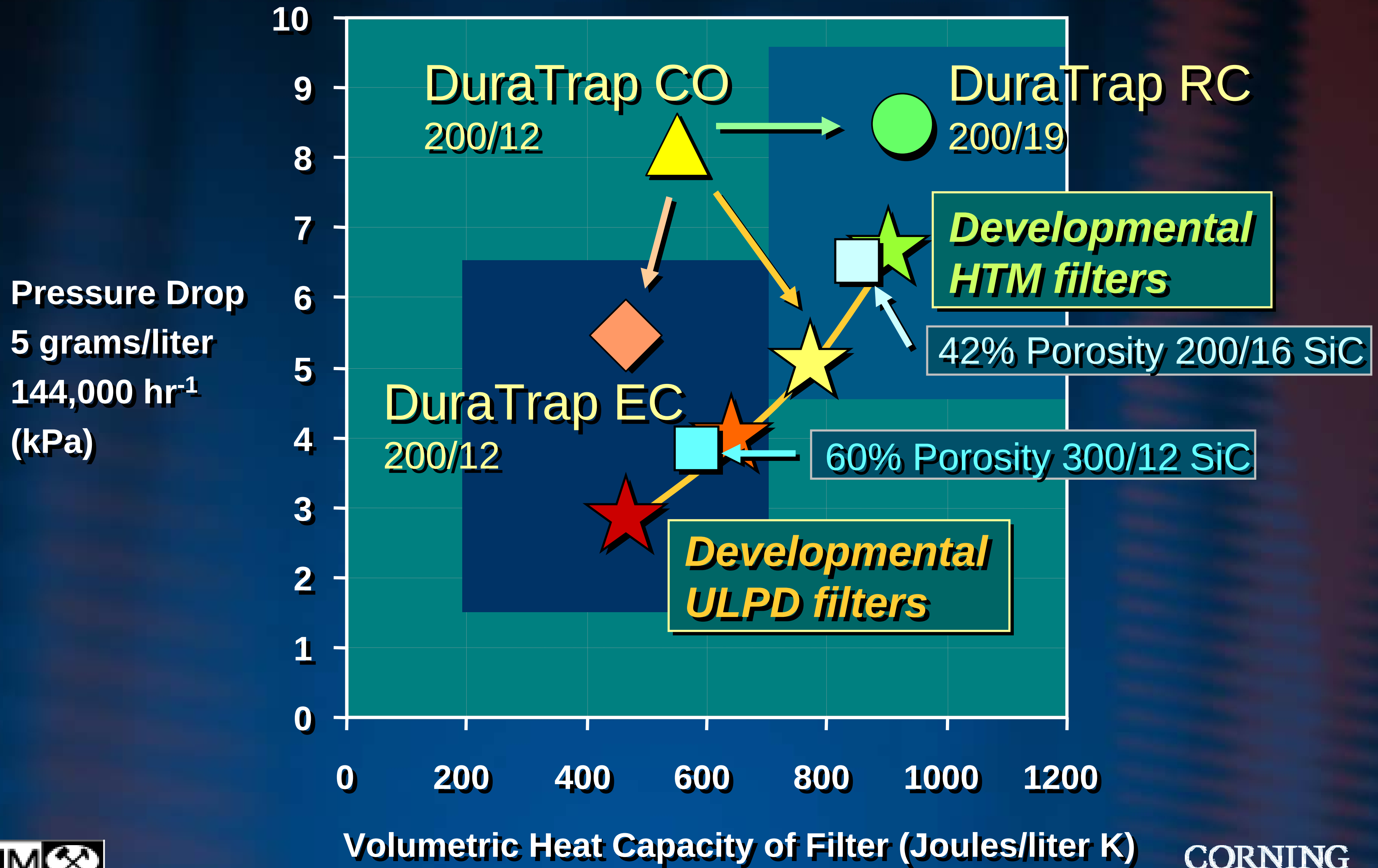
Pressure Drop vs Volumetric Heat Capacity of Bare Filters



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Summary

- By tailoring the ceramic pore microstructure or catalyst formulation, very low pressure drops have been achieved for catalyzed cordierite DPFs
- Soot-loaded ΔP for bare or catalyzed filters is minimized for high pore connectivity *(high porosity or narrow psd)*
- Bare or catalyzed filters with moderate %porosity and fine, narrow pore size distribution yield soot-loaded ΔP equivalent to high-porosity filters with coarse, broad pore size distribution

Conclusion

- Research on effects of pore microstructure, cell geometry, and catalyst formulation have yielded new catalyzed cordierite DPFs with unique combinations of low ΔP, high %FE, and higher thermal mass, without sacrificing strength

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